

A benchmarking exercise for three longitudinal strength models for unidirectional fibre-reinforced composites

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Abstract

The longitudinal strength of unidirectional fibre-reinforced composites is a basic, but vital property needed in many calculations and simulations. Reliably predicting it however, is a challenging task that many researchers have attempted to address. It is challenging to reliably compare the different fibre break models as they are often based on a different set of assumptions and use different modeling tools. Some models use many assumptions, but are fast and can simulate large composites. Other models use less assumptions, but are slower and limited to smaller composites. Assessing such differences is difficult based on the available literature. A benchmarking exercise was therefore set up to compare three fibre break models: a hierarchical scaling law [1], a direct numerical simulation [2-4], and a multiscale FE² simulation [5-7]. The comparison was based on blind predictions for two cases: (1) a hypothetical fibre/matrix combination without any experimental data, and (2) a T800/M21 composite for which experimental fibre break development was measured using synchrotron computed tomography. The goals of the exercise were to:

- Compare model predictions with detailed experimental data
- Establish benefits and drawbacks of the models
- Establishing gaps in the literature and propose future improvements

The first case was a hypothetical composite with a given set of material properties that did not correspond any factual experimental data. This case allowed a truly blind comparison of the models, as there was no way of knowing what the expected strength should be. Figure 1 reveals that the direct numerical simulation with a plastic matrix predicts higher strength values than the other two models, which both use the elastic matrix. While there are important differences in terms of how stress concentrations are implemented, the key difference is how models deal with clusters of fibre breaks. All three models allow fibre breaks to occur anywhere near an existing fibre break, but once the second break has been detected, the hierarchical scaling law and multiscale FE² simulations assume it to be co-planar with the other fibre break. Co-planar fibre breaks are the worst-case scenario, as they amplify the stress concentrations. This assumption therefore lowers the predicted strength, although it is difficult to judge how large the effect is. Another conclusion is that not including the plasticity of the matrix leads to significant overestimations.

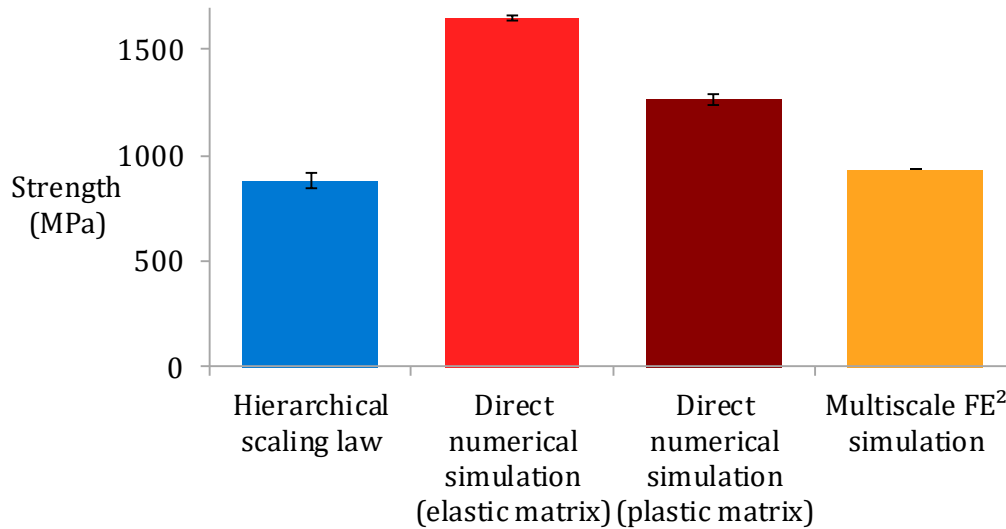


Figure 1: Comparison of the longitudinal tensile strength predicted by the three models for a hypothetical fibre/matrix combination.

The second case is for a T800/M21 composite (see Figure 2). The results were only revealed to the participants after the modelling predictions had been submitted. This case was not truly blind as it is not difficult to estimate what strength should be expected for a T800/M21 composite. The observed trends are similar to the ones in Figure 1: the direct numerical simulation predicts a higher strength, and the predictions of the two other models are relatively close to each other. The results again reveal the importance of using the right material properties for the matrix.

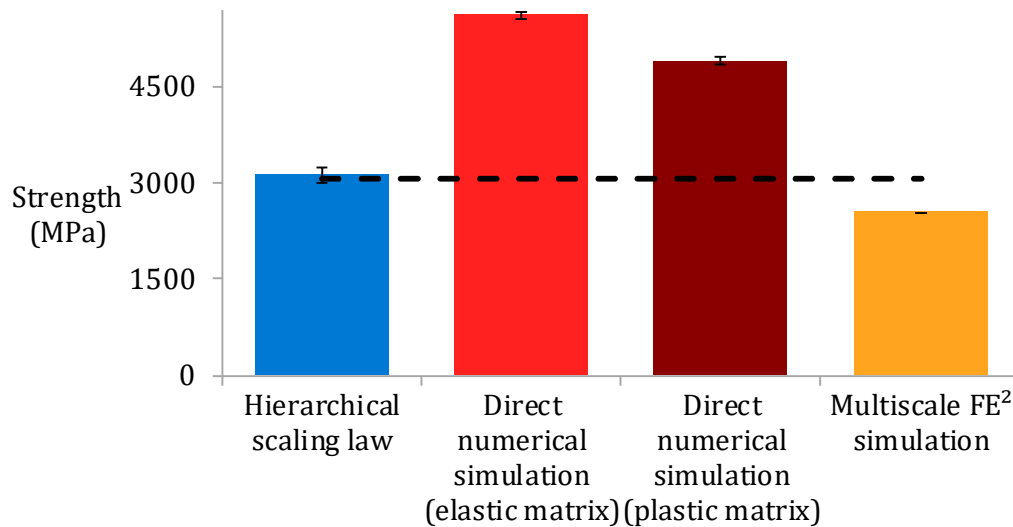


Figure 2: Comparison of the longitudinal tensile strength predicted by the three models for the T800/M21. The black dots and dotted line indicates the experimental data.

A much more detailed comparison has been performed, which also looks at fibre break cluster development and computational time. This leads to further insights into the differences between the models, how they affect the predicted results and in which direction future research in this area should evolve.

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